MICROMETER WIRES.

R. H. WARD, M. D., F. R. M. S., Troy, N. Y.

The production of fine wires for micrometer purposes has attained a success which does not seem to be adequately realized. At least, that there is great misconception prevalent concerning it may be inferred from the recent appearance of several magazine articles, mentioning as a novelty the drawing out of platinum in the form of a core imbedded in silver, stating the sizes used in micrometers at $\frac{1}{1250}$ inch in comparison with spider thread stated at $\frac{1}{2300}$ inch, and (a rather obvious induction from these data) representing the wire as comparatively inapplicable to micrometry.

Early in this century Dr. Wm. H. Wollaston (see Phil. Trans. Roy. Soc. Lond., 1813, pp. 114–118), at the suggestion of the claim that an artist of Augsburg had drawn wire so slender that 500 feet in length weighed only one grain, undertook to make such wire by inserting, in a hole drilled longitudinally through the center of a cylinder of pure silver, a gold wire of one-tenth the diameter of the silver, and then drawing down the compound cylinder thus formed to $\frac{1}{500}$ inch. The gold core of this compound wire, which remained after the silver was dissolved off with acid, was a wire of $\frac{1}{5000}$ inch, of which 550 feet weighed one grain. Finding unexpected difficulty in drilling through the fine silver bars, on account of the toughness of the metal, a platinum wire was substituted for the gold core. This was sufficiently infusible to be stretched in the center of a mould while melted silver was cast around it, giving a pencil $\frac{1}{3}$ inch in diameter, from which a platinum wire of $\frac{1}{4000}$ inch was obtained with great facility. This size Dr. Wollaston considered as fine as desirable for micrometers, for the reason that such a wire, in any telescope likely to be useful, would subtend an angle of less than one second of a degree. He, however, found that the tenacity of the metals was increased by drawing out, as happens to most metals within moderate limits, so that good wire was produced $\frac{1}{18000}$ inch in diameter, and

with a breaking strain of $1\frac{1}{3}$ grains. Beyond this fineness the limit of ductility seemed to be passed, the wire being of poor quality and frequently interrupted, though some pieces as fine as $\frac{1}{30000}$ inch were produced. Though Dr. Wollaston seemed wholly satisfied with the result of his experiment, his method does not seem to have been very promptly adopted, probably on account of the extreme difficulty of successfully handling the wire. So great is this difficulty that the writer has known of several cases where coarse and unsatisfactory vegetable fibers were substituted, without notice or consent, by manufacturers from whom wires had been ordered.

In 1874 Mr. E. W. Arms, C. E., of this city, undertook to prepare and mount platinum wires, made after Dr. Wollaston's method, as an improvement upon the spider cross-lines formerly used in the telescopes of surveying instruments manufactured by W. & L. E. Gurley, with whose establishment he was and is connected. He succeeded in producing satisfactory lines of $\frac{1}{10000}$ inch in diameter, but failed to mount them successfully. In 1875 one of the Messrs. Gurley brought from Europe for comparison and experiment two samples of platinum wire, obtained after a somewhat diligent search, in several cities, for the finest that could be supplied by the trade. These samples, from London and Paris respectively, measured about $\frac{1}{7500}$ inch each. The size promised from London was $\frac{1}{10000}$ inch, but no offer of anything finer could be obtained, and the fulfillment fell far short of even that moderate limit. It need scarcely be added that the effort to purchase a supply was abandoned, and that the wire drawn by Mr. Arms was adopted for subsequent experiments. Before the end of that year, 1875, the process was under complete control, and the wires were handled with the same certainty that pertains to other branches of the business.

Plain platinum wire is first drawn to the size of not less than .0032 inch. It is then covered with sufficient cast silver to form a compound bar of .15 inch, this pencil being subsequently drawn until elongated nearly 3000 times, its core having attained any required degree of fineness to .00007 inch. By further increasing the proportion of silver a fineness of .00002 inch has been attained, and without any indication that the limit of ductility of the platinum had been reached; though such fine sizes are not yet known to be useful, while the difficulties of manipulation increase so rapidly as

to cause a great addition of cost. Three inches of the finest wire, drawn without imbedding, will make hundreds of feet of the coarsest micrometer size, of which about 2000 feet would weigh one grain, while a pound (avoirdupois) would be nearly long enough to reach from here to England, and at fifty cents per foot would cost seven million dollars ($7,000,000), constituting an interesting if not an unparalleled example of enormous increase of value acquired during the process of manufacture. Though an ounce would satisfy, at the present rate, the demand of the world for centuries, an order for that apparently moderate quantity was once received by the Messrs. Gurley from a buyer who required a little and had forgotten to ask or figure the probable cost. When made aware of the real character of his order, he found himself well satisfied with a much smaller quantity.

The sizes of the wires produced, as measured under the microscope, correspond very closely, as of necessity they must, with the sizes computed on the principles of ratios according to the method of manufacture.

The wire as produced is smooth and of good quality, and sufficiently strong for the purposes required, a line of .0001 in. easily supporting a weight of three grains. Evidently it will not bear rough handling; though in habitual and extensive use for at least ten years it is not known to deteriorate with time or reasonable use. Though less affected by variations of temperature than other metals, its very limited elasticity presents a limit to the employment of long pieces, on account of the difficulty of making them taut.

Mr. Arms has also succeeded in casting silver around a gold core, thus obviating Dr. Wollaston's difficulty in regard to that metal. Gold, however, is more affected by temperature than platinum, and is not known to possess any comparative advantage for micrometry. Neither is German silver, which has been lately recommended as superior, believed to be as available as platinum.

The primary object of the manufacture of this wire for telescope micrometers has been accomplished beyond question, and for this purpose the Messrs. Gurley employ several hundred feet a year for instruments of their own manufacture. The instruments so fitted are more satisfactory by the ultimate test of use in the field than

those with spider lines, the wires being seen with great distinctness, and, therefore, capable of being brought into position with ease and precision, being probably much more durable, on the average, and, therefore, less likely to cause delay and disappointment, and being unaffected by damp weather, which often causes the spider lines to become crooked. The wire micrometers are preferred almost unanimously by the engineers and surveyors who have used them, and a great many old instruments with spider lines have been sent back to have wires substituted. The practical limit to the fineness of the wires used is not the possibility of drawing the wire, but the desire of those who use the instruments; the aim being to supply a line large enough to be seen with the greatest ease and distinctness, and yet not large enough to obstruct unnecessarily the field of view. In selecting the size of wire first adopted, a spider thread from a favorite micrometer was taken as a standard and the wire drawn down to match that by direct comparison. The recent tendency to employ higher oculars than formerly has called for a corresponding increase in the fineness of the wires fitted to them. The size most used at present is .00009 in., which answers well for a $\frac{3}{4}$ or $\frac{4}{10}$ ocular, while .0001 in. is preferred for low powers, and .00007 in. for higher ones.

Large quantities of the wire have been made to order for other uses in this country and for exportation to Europe. They have been employed, for instance, by the United States Signal Service for suspending galvanometer needles; and by the Engineer's Department of the United States Army for exploding submarine torpedoes, the fuses made from them far exceeding in sensitiveness any known before. For this purpose a diameter of .0002 in. has been employed. (See Reports of the Chief Engineers of the United States Army, 1884, Pt. 1, p. 59, where, however, there seems to be an error, probably a misprint, of one place of decimals in stating the diameter of the wire formerly used.)

For use in the Ramsden or other ocular micrometer as a portion of the microscope (and also, presumably, in the astronomical telescope), the wires seem, from present limited experience, to possess unqualified advantages. In size, they do not compare unfavorably with the spider thread, as they can be made to the same sizes

as the threads commonly used, and very much finer if desired, with the additional merit that they can be replaced or duplicated with the expectation of their conforming to the size ordered, which is far from true with the indefinitely varying cobwebs. Nor is smallness an unlimited advantage; they may be made too fine. No capable person would probably attempt to measure by the blundering method of centering his micrometer upon a line or point of structure in the object, since a far greater precision can be attained by bringing the lines carefully together and taking the point of optical contact, and this seems to be accomplished best when the micrometer line is perfectly opaque, notwithstanding the fact that the partial transparency of the spider thread has been mentioned as a comparative advantage, and when it has a barely visible thickness.

The writer had the cobwebs removed from a micrometer that had been made by one of the most reputable makers in the world, with very manifest and unquestionable improvement. In fact, he had one thread only changed at first, in order to compare *in situ* the new wire with the remaining spider thread. The comparison in this condition was simply ridiculous, and it is literally true that every one to whom it was shown laughed at it. It was difficult to believe, when thus compared with the cleaner cut and beautifully opaque wire, which, though very much smaller, looked far more distinct, that the spider line by its side had ever been considered good or that it could have been sent out from the shop where it was known to have been made.

As to durability, the wires are practically permanent when well mounted and carefully used, which is in great contrast to the experience with spider threads. As cobweb micrometers are rather cumbersome and costly, and few microscopists keep a box full at hand to draw from, the liability to fail at a critical point in some important and urgent work is a very serious inconvenience, especially as the repairs required cannot always be obtained promptly, and in some localities not without sending the apparatus away from home.

On the whole, the writer's experience has given him, as yet, no desire to return to the uncertain cobweb, his experience in this respect being in conformity with that of those engineers who use the wires in the oculars of their telescopes.